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[0074] where R_1, R_3, R_{13}, R_2, R_4, R_{24} are defined as shown in Equation (17):

$$R_1 = \frac{(r_1 h_1^* + r_2^* h_2 + r_3^* h_3 - r_4 h_4^*)}{K}, \tag{17}$$

$$R_3 = \frac{(r_1 h_4^* + r_2^* h_3 - r_3^* h_2 + r_4 h_1^*)}{K}$$

$$R_{13} = \frac{(-h_1 h_4^* + h_1^* h_4 - h_2^* h_3 + h_2 h_3^*)}{K},$$

$$R_2 = \frac{(r_1 h_2^* - r_2^* h_1 + r_3^* h_4 + r_4 h_3^*)}{K}$$

$$R_4 = \frac{(r_1 h_3^* - r_2^* h_4 - r_3^* h_1 - r_4 h_2^*)}{K},$$

$$R_{24} = \frac{(-h_2 h_3^* - h_1^* h_4 + h_4^* h_1 + h_3 h_2^*)}{K}$$

$$K = |h_1|^2 + |h_2|^2 + |h_3|^2 + |h_4|^2$$

[0075] The threshold detector **460** pre-detects symbols that approximate R_1 and R_3 and the threshold detector **465** pre-detects symbols that approximate R_2 and R_4. The deciders **462** and **467** then compute whether $|R^{13}-x_1{}^*x_3|^2-|x_1|^2|x_3|^2$ and $|R_{24}-x_2{}^*x_4|^2-|x_2|^2|x_4|^2$ are minima. If they are minima, the deciders **462** and **467** output the pre-detected symbols as final symbols. The metric calculators **370** and **375** detect symbols that minimize formulas (15) and (16) only when $|R_{13}-x_1{}^*x_3|^2-|x_1|^2|x_3|^2$ and $|R^{24}-x_2{}^*x_4|^2-|x_2|^2|x_4|^2$ are not minima.

[0076] As described above, the present invention achieves a maximum diversity order without data rate loss even when complex symbols are transmitted. It also minimizes transmission latency. The resulting robustness against fast fading and simplified decoding design reduce production cost and contribute to system miniaturization.

[0077] While the invention has been shown and described with reference to a certain preferred embodiment thereof, it will be understood by those skilled in the art that various changes in form and details may be made therein without departing from the spirit and scope of the invention as defined by the appended claims.

What is claimed is:

1. A receiver for receiving complex symbols in a radio communication system, comprising:

a symbol arranger for collecting signals from at least one receiver antenna over four time intervals, the at least one receiver antenna receiving the signals from at least three transmitter antennas;

a channel estimator for estimating at least three channel gains from the at least three transmitter antennas to the at least one receiver antenna;

a first decoder for computing metrics for all possible pairs of symbols using the received signals and the channel gains, and for detecting two symbols giving a minimum metric;

a second decoder for computing metrics for all possible pairs of symbols using the received signals and the channel gains, and for detecting two symbols giving a minimum metric; and

a parallel-to-serial converter for arranging the four symbols detected by the first and second decoders in the right order,

wherein the first and second decoders each linearly operate the received signals with the channel gains, pre-detect two symbols using threshold detection, and output the pre-detected two symbols as final symbols if the product of the product of the pre-detected symbols and a constant determined by the channel gains is a minimum.

2. The receiver of claim 1, wherein the number of the transmitter antennas is 3.

3. The receiver of claim 2, wherein the first and second decoders each pre-detect two symbols s_1 and s_3 or s_2 and s_4, respectively, that minimize $|R_1-e^{j\theta_1}s_1|^2+|R_3-s_3|^2$ or $|R_2-s_2|^2+|R_4-e^{j\theta_4}s_4|^2$, respectively, where θ_1 and θ_4 are phase rotation values used in a transmitter,

$$R_1=r_1h_1{}^*+r_2{}^*h_2+r_3{}^*h_3,\ R_3=r_2{}^*h_3+r_4h_1{}^*+-r_3{}^*h_2,$$

$$R_2=r_1h_2{}^*-r_2{}^*h_1+-r_4h_3{}^*,\ R_4=r_1h_3{}^*-r_3{}^*h_1-r_4h_2{}^*,$$

r_1, r_2, r_3 and r_4 are the signals received over the four time intervals, and h_1, h_2, and h_3 are the channel gains of the three antennas.

4. The receiver of claim 3, wherein the first and second decoders output the pre-detected symbols as final symbols if $(C_3)Re\{e^{-j\theta_1}s_1{}^*s_3\}$ or $(-C_3)Re\{s_2{}^*e^{j\theta_4}s_4\}$ is a minimum, where $C_3=h_3h_2{}^*-h_3{}^*h_2$ and h_2 and h_3 are the channel gains of two of the three transmitter antennas.

5. The receiver of claim 4, wherein the first and second decoders detect two symbols s_1 and s_3 or s_2 and s_4, respectively, that minimize

$$|R_1-e^{j\theta_1}s_1|^2+|R_3-s_3|^2+2(C_3)Re\{e^{-j\theta_1}s_1{}^*s_3\} \text{ or}$$

$$|R_2-s_2|^2+|R_4-s^{j\theta_4}s_4|^2+2(-C_3)Re\{s_2{}^*e^{j\theta_4}s_4\},$$

respectively, if $(C_3)Re\{e^{-j\theta_1}s_1{}^*s_3\}$ or $(-C_3)Re\{s_2{}^*e^{j\theta_4}s_4\}$ is not a minimum.

6. The receiver of claim 1, wherein the number of the transmitter antennas is 4.

7. The receiver of claim 6, wherein the first and second decoders each pre-detect two symbols s_1 and s_3 or s_2 and s_4, respectively, that minimize $|R_1-e^{j\theta_1}s_1|^2+|R_3-s_3|^2$ or $|R_2-s_2|^2+|R_4-e^{j\theta_4}s_4|^2$, respectively, in which θ_1 and θ_4 are phase rotation values used in a transmitter, and R_1, R_3, R_2, and R_4 are defined as

$$R_1 = \frac{(r_1 h_1^* + r_2^* h_2 + r_3^* h_3 - r_4 h_4^*)}{K},$$

$$R_3 = \frac{(r_1 h_4^* + r_2^* h_3 - r_3^* h_2 + r_4 h_1^*)}{K}$$

$$R_2 = \frac{(r_1 h_2^* - r_2^* h_1 + r_3^* h_4 + r_4 h_3^*)}{K},$$

$$R_4 = \frac{(r_1 h_3^* - r_2^* h_4 - r_3^* h_1 - r_4 h_2^*)^2}{K}$$

$$K = |h_1|^2 + |h_2|^2 + |h_3|^2 + |h_4|^2$$

where r_1, r_2, r_3 and r_4 are the signals received over the four time intervals, and h_1, h_2, h_3, and h_4 are the channel gains of the four antennas.

8. The receiver of claim 7, wherein the first and second decoders output the pre-detected symbols as final symbols if $|R_{13}-x_1{}^*x_3|^2-|x_1|^2|x_3|^2$ or $|R_{24}-x_2{}^*x_4|^2-|x_2|^2|x_4|^2$ is a minimum, where R_{13} and R_{24} are defined as

$$R_{13} = \frac{(-h_1 h_4^* + h_1^* h_4 - h_2^* h_3 + h_2 h_3^*)}{K},$$

$$R_{24} = \frac{(-h_2 h_3^* - h_1^* h_4 + h_4^* h_1 + h_3 h_2^*)}{K}$$

9. The receiver of claim 8, wherein the first and second decoders each detect two symbols s_1 and s_3 or s_2 and s_4, respectively, that minimize

$$|R_1-x_1|^2+|R_3-x_3|^2+2(C_3)Re\{x_1{}^*x_3\} \text{ or}$$

$$|R_2-x_2|^2+|R_4-x_4|^2+2(C_3)Re\{x_2{}^*x_4\},$$

respectively, if $|R_{13}-x_1{}^*x_3|^2-|x_1|^2|x_3|^2$ or $|R^{24}-x_2{}^*x_4|^2-|x_2|^2|x_4|^2$ is not a minimum.

10. The receiver of claim 1, wherein each of the first and second decoders comprises:

a symbol generator for generating all possible symbol sub-combinations, each symbol sub-combination containing two symbols;

a phase rotator for rotating the phase of one symbol in each symbol sub-combination by a predetermined value;

a threshold detector for linearly operating the received signals with the channel gains and pre-detecting two symbols using threshold detection;

a decider for computing that the pre-detected symbols are final symbols if the product of the product of the pre-detected symbols and a constant determined by the channel gains is a minimum;

a metric calculator for computing the metrics of the symbol sub-combinations, each containing a phase-rotated symbol, using the received signals and the channel gains; and

a detector for detecting two symbols having a minimum metric using the computed metrics.

11. The receiver of claim 10, wherein the number of the transmitter antennas is 3.

12. The receiver of claim 11, wherein the threshold detector pre-detects two symbols s_1 and s_3 or s_2 and s_4 that minimize $|R_1-e^{j\theta_1}s_1|^2+|R_3-s_3|^2$ or $|R_2-s_2|^2+|R_4-e^{j\theta_4}s_4|^2$ where θ_1 and θ_4 are phase rotation values used in a transmitter,

$$R_1=r_1h_1{}^*+r_2{}^*h_2+r_3{}^*h_3,\ R_3=r_2{}^*h_3+r_4h_1{}^*+-r_3{}^*h_2,$$

$$R_2=r_1h_2{}^*-r_2{}^*h_1+r_4h_3{}^*,\ R_4=r_1h_3{}^*-r_3{}^*h_1-r_4h_2{}^*,$$

r_1, r_2, r_3 and r_4 are the signals received over the four time intervals, and h_1, h_2, and h_3 are the channel gains of the three antennas.

13. The receiver of claim 12, wherein the decider outputs the pre-detected symbols as final symbols if $(C_3)Re\{e^{-j\theta_1}s_1{}^*s_3\}$ or $(-C_3)Re\{s_2{}^*e^{j\theta_4}s_4\}$ is a minimum, where $C_3=h_3h_2{}^*-h_3{}^*h_2$ and h_2 and h_3 are the channel gains of two of the three transmitter antennas.

14. The receiver of claim 13, wherein the metric calculator detects two symbols s_1 and s_3 or s_2 and s_4 that minimize

$$|R_1-e^{j\theta_1}s_1|^2+|R_3-s_3|^2+2(C_3)Re\{e^{-j\theta_1}s_1{}^*s_3\} \text{or}$$

$$|R_2-s_2|^2+|R_4-s^{j\theta_4}s_4|^2+2(-C_3)Re\{s_2{}^*e^{j\theta_4}s_4\}$$

if $(C_3)Re\{e^{-j\theta_1}s_1s_3\}$ or $(-C_3)Re\{s_2e^{j\theta_4}s_4\}$ is not a minimum.

15. The receiver of claim 10, wherein the number of the transmitter antennas is 4.

16. The receiver of claim 15, wherein the threshold detector pre-detects two symbols s_1 and s_3 or s_2 and s_4 that minimize $|R_1-c^{j\theta_1}s_1|^2+|R_3-s_3|^2$ or $|R_2-s_2|^2+|R_4-c^{j\theta_4}s_4|^2$, in which θ_1 and θ_4 are phase rotation values used in a transmitter, and R_1, R_3, R_2, and R_4 are defined as

$$R_1 = \frac{(r_1 h_1^* + r_2^* h_2 + r_3^* h_3 - r_4 h_4^*)}{K},$$

$$R_3 = \frac{(r_1 h_4^* + r_2^* h_3 - r_3^* h_2 + r_4 h_1^*)}{K}$$

$$R_2 = \frac{(r_1 h_2^* - r_2^* h_1 + r_3^* h_4 + r_4 h_3^*)}{K},$$

$$R_4 = \frac{(r_1 h_3^* - r_2^* h_4 - r_3^* h_1 - r_4 h_2^*)^2}{K}$$

$$K = |h_1|^2 + |h_2|^2 + |h_3|^2 + |h_4|^2$$

where r_1, r_2, r_3 and r_4 are the signals received over the four time intervals, and h_1, h_2, h_3, and h_4 are the channel gains of the four antennas.

17. The receiver of claim 16, wherein the decider outputs the pre-detected symbols as final symbols if $|R^{13}-x_1{}^*x_3|^2-|x_1|^2|x_3|^2$ or $|R_{24}-x_2{}^*x_4|^2-|x_2|^2|x_4|^2$ is a minimum, where R_{13} and R_{24} are defined as

$$R_{13} = \frac{(-h_1 h_4^* + h_1^* h_4 - h_2^* h_3 + h_2 h_3^*)}{K},$$

$$R_{24} = \frac{(-h_2 h_3^* - h_1^* h_4 + h_4^* h_1 + h_3 h_2^*)}{K}$$

18. The receiver of claim 17, wherein the metric calculator detects two symbols s_1 and s_3 or s_2 and s_4 that minimize

$$|R_1-x_1|^2+|R_3-x_3|^2+2(C_3)Re\{x_1{}^*x_3\} \text{ or}$$

$$|R_2-x_2|^2+|R_4-x_4|^2+2(C_3)Re\{x_2{}^*x_4\}$$

if $|R_{13}-x_1x_3|^2-|x_1|^2|x_3|^2$ or $|R_{24}-x_2{}^*x_4|^2-|x_2|^2|x_4|^2$ is not a minimum.

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